TITLE OF THE INVENTION

3D IMAGE PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a 3D image processing apparatus.

2. Description of the Related Art

A highly precise blood vessel structure can be extracted from a 3D-DSA image reconstructed from a plurality of DSA (Digital Subtraction Angiography) images corresponding to a plurality of projection directions. 3D-DSA images therefore are very useful for IVR support. In subtraction processing, however, the data of bones and soft tissues, other than contrasted blood vessels, are removed. 3D-DSA images therefore include no bone structure. For this reason, the 3D-DSA images are low in utility for surgical operation support. A 3D-DA image reconstructed from a plurality of DA (Digital Angiography) images corresponding to a plurality of projection directions includes a bone structure and blood vessel structure. An observer can therefore grasp the position of the blood vessel relative to the bone from the 3D-DA image. However, it is difficult to separate blood vessels from bones and soft tissues in a 3D-DSA image clearly.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to

separate blood vessels from bones clearly, and to display blood vessels in high definition.

According to a aspect of the present invention, there is provided the 3D image processing apparatus comprises a storing unit storing mask images corresponding to projection directions associated with a subject contrast images corresponding to the projection directions, a subtracting unit generating subtraction images by subtracting the mask images from the contrast images, a reconstruction unit reconstructing first volume data from the mask images and reconstructs second volume data from the subtraction images, an image processing unit generating a first 3D image representing a bone structure and/or a soft tissue structure from the first volume data, and generates a second 3D image representing a contrasted blood vessel from the second volume data, an image synthesizing unit generating a synthetic image by synthesizing the first 3D image with the second 3D image, and a displaying unit displaying the synthetic and/or individual images.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a block diagram showing the arrangement of a 3D image processing apparatus according to an embodiment;

FIG. 2 is a perspective view showing the outer appearance of an X-ray imaging mechanism in FIG. 1;

FIGS. 3A and 3B are supplementary views of

distortion correction processing in a 3D reconstruction processing unit in FIG. 1;

FIG. 4 is a view showing the pre-processing in the 3D image processing apparatus in FIG. 1;

FIG. 5 is a view showing the first processing sequence in the 3D image processing apparatus in FIG. 1;

FIG. 6 is a view showing the second processing sequence in the 3D image processing apparatus in FIG. 1;

FIG. 7 is a view showing the third processing sequence in the 3D image processing apparatus in FIG. 1;

FIG. 8A is a view showing contrast images;

FIG. 8B is a view showing mask images;

FIG. 8C is a view showing DSA images;

FIG. 9A is a view showing volume data corresponding to the contrast images;

FIG. 9B is a view showing volume data corresponding to the mask images;

FIG. 9C is a view showing volume data corresponding to the DSA images; and

FIG. 10 is a view showing a 3D angio/bone image.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. 1, a 3D X-ray diagnosing apparatus has an X-ray imaging mechanism 10 and 3D image processing apparatus 1. As shown in FIG. 2, the

X-ray imaging mechanism 10 has an X-ray tube 12 and
detection system 14. The detection system 14 is
constituted by an image intensifier and TV camera. The
detection system 14 may be formed from a flat panel

5 detector. The X-ray tube 12 is mounted on a C-arm 160
together with the detection system 14. An object P to
be examined on a top 50 of a bed is placed between the
X-ray tube 12 and the detection system 14. The C-arm
160 is supported by a support 164 suspended from the

10 ceiling. The C-arm 160 can rotate along three
orthogonal axes A, B, and C.

The 3D image processing apparatus 1 includes a
control unit 37 serving as a main component, an A/D
converter 21, an input device 22, a storing unit 23, a

15 subtracting unit 31, a distortion correcting unit 32,
an affine converter 36, a 3D reconstruction processing
unit 33, a 3D image processing unit 35, an image
synthesizing unit 34, a D/A converter 38, and a
displaying unit 39. The A/D converter 21 is connected

20 to the detection system 14. The D/A converter 38 is
connected to the displaying unit 39. The input device
22 has a keyboard and mouse. The storing unit 23
stores various data such as image data, volume data,
and synthetic image data input through the A/D

25 converter 21. The subtracting unit 31 has a function
of subtracting image data and a function of subtracting
image data or volume data. In the subtracting process

of the former, a logarithm natural of two data is computed, and the two data are subtracted after that. In the subtracting process of the latter, a two data are subtracted directly. The former is named as the

5   first subtracting process, and the latter is named as the second subtracting process in the following. The distortion correcting unit 32 has distortion correction processing for correcting image distortion to originate in the Image Intensifie. The affine converter 36

10   performs enlargement processing and movement processing.

The 3D reconstruction processing unit 33 reconstructs volume data from a plurality of image data corresponding to a plurality of projection directions.

15   The 3D image processing unit 35 generates 3D image data from volume data by surface rendering processing. The image synthesizing unit 34 generates synthetic image data by synthesizing two or more kinds of 3D images.

The operation of this embodiment will be described

20   next. A contrast media is injected into a blood vessel of the object. Before the contrast media is injected into the object, a plurality of image data corresponding to a plurality of projection directions are acquired. Images acquired before injection of the

25   contrast media are called mask images. The mask images include an image of a bone and an image of a soft tissue. Pixel values in the respective images reflect

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transmittances unique to the bone and soft tissue.

After the contrast media is injected, a plurality
of image data corresponding to a plurality of
projection directions are acquired. Images acquired
5   after injection of the contrast media are called
contrast images. The plurality of projection
directions to which the plurality of contrast images
correspond coincide with the plurality of projection
directions to which the plurality of mask images
10   correspond. The contrast images include an image of
the bone, an image of the soft tissue, and an image of
the blood vessel. A pixel value in the image of the
bone reflects a transmittance unique to the bone. A
pixel value in the image of the soft tissue reflects
15   a transmittance unique to the soft tissue. A pixel
value in the image of the blood vessel reflects a
transmittance unique to the contrast media in the blood
vessel instead of the blood vessel. The transmittance
of the contrast media is much lower than that of the
20   blood vessel.

In practice, for example, imaging is repeated
200 times at 1°-intervals while the C-arm 160 rotates
(A or B) at high speed. As a consequence, 200 mask
images (200 frames) are obtained. The 200 mask images
25   correspond to 200 projection directions. The 200
contrast images obtained by imaging after injection of
the contrast media correspond to the 200 projection

directions. The 200 contrast images respectively correspond to the 200 mask images. A given mask image coincides in projection direction with a corresponding contrast image.

5   The data of the 200 mask images are stored in the storing unit 23. Likewise, the data of the 200 contrast images are stored in the storing unit 23. These mask image data and contrast image data are subjected to distortion correction processing by the

10   distortion correcting unit 32, as shown in FIG. 4. For the sake of simplicity, consider, as distortion correction processing, processing using a phantom having wires arranged at equal intervals vertically and horizontally in the form of a square lattice. When

15   imaging is performed after this phantom is placed on the detection surface of the detection system 14, a projection image of the phantom ideally has a square lattice shape, as shown in FIG. 3B. In practice, however, the projection image of the phantom undergoes

20   pincushion distortion due to the shape of the detection surface of the detection system 14 and sigmoid distortion due to geomagnetism, as shown in FIG. 3A. For this reason, the distorted image data shown in FIG. 3A is acquired in advance, and the intersections

25   of the wires are extracted as lattice points from this distorted image data. These lattice points should be arranged at equal intervals in the absence of

distortion. Therefore, correction vectors for arraying the lattice points at equal intervals are obtained for each lattice point. The mask and contrast images are corrected in accordance with the correction vectors.

5   Points other than the lattice points are corrected by using the data of neighboring lattice points. Note that since different distortion distributions appear at different angles, a distortion distribution table measured from acquired angle-specific phantom

10   projection images is held, and distortion is corrected on the basis of the table.

The subtracting unit 31 corrects density non-uniformlty in a mask image. Likewise, the subtracting unit 31 corrects density non-uniformlty in a contrast

15   image. The processing for correcting density non-uniformlty subtracts a image for correcting density non-uniformlty from a mask or contrast image in the first subtracting process. The image for correcting density non-uniformlty is obtained by imaging in a

20   state wherein nothing other than air is interposed between the X-ray tube 12 and the detection system 14.

This embodiment provides three kinds of 3D image processes for separately generating 3D image data representing a bone structure and 3D image data

25   representing a contrasted blood vessel structure. The three kinds of 3D image processes are shown in FIGS. 4, 5, and 6. A desired one of the three kinds of 3D image

processing is selected by an operator through the input
device 22. An angio-image and bone image are generated
by the selected process. A synthetic image of the
generated angio-image and bone image is displayed.

5   The three kinds of 3D image processes will be
sequentially described below.

As shown in FIG. 5, in the first 3D image process,
first of all, the subtracting unit 31 subtracts a
plurality of corrected mask images (see FIG. 8B) in

10   different projection directions from a plurality of
corrected contrast images (see FIG. 8A) in different
projection directions in the second subtracting
process. When it says concretely, the respective
corrected mask images are subtracted from the

15   corresponding corrected contrast images in the same
projection directions as those of the mask images. As
a consequence, a plurality of DSA images (see FIG. 8C)
are generated. Each corrected mask image includes an
image of a bone and an image of a soft tissue. Each

20   corrected contrast image includes an image of the bone,
an image of the soft tissue, and an image of the
contrasted blood vessel. Each DSA image substantially
includes only an image of the contrasted blood vessel.

A plurality of mask images are subjected to 3D

25   reconstruction processing by the 3D reconstruction
processing unit 33. As a consequence, volume data
(mask) is generated (see FIG. 9B). The volume data

(mask) includes the 3D structure of the bone, the 3D structure of the soft tissue. A plurality of DSA images are subjected to 3D reconstruction processing by the 3D reconstruction processing unit 33. As a

5   consequence, volume data (DSA) is generated (see FIG. 9C). The volume data (DSA) includes only the 3D structure of the contrasted blood vessel.

As a reconstruction method, the filtered back projection method proposed by Feldkamp et al. is

10   generally used. An appropriate convolution filter such as a Shepp-Logan filter or Ramachandran filter is applied to the 200 DSA images. The 200 DSA images processed by the convolution filter are then subjected to back projection operation. As a consequence, volume

15   data (DSA) is generated. Likewise, an appropriate convolution filter is applied to the 200 corrected mask images. The 200 corrected mask images processed by the convolution filter are then subjected to back projection operation. As a consequence, volume data

20   (mask) is generated.

In this case, a reconstruction region is defined as a cylinder inscribed in an X-ray beam from the X-ray tube 12 in all directions. The inside of this cylinder is three-dimensionally discretized with a length d at

25   the central portion of the reconstruction region projected by the width of one detection element of the detection system 14, and a reconstructed image based on

the data of each discrete point must be obtained.
Although an example of the discrete interval is
described, this value may differ depending on the
apparatus or maker. Basically, therefore, it suffices

5   if the discrete interval defined for each apparatus be
used.

The volume data (mask) is subjected to surface
rendering processing by the 3D image processing unit
35. This generates a 3D image (3D bone image)

10   representing the 3D structure of the bone. The volume
data (DSA) is subjected to surface rendering processing
by the 3D image processing unit 35. This generates a
3D image (3D angio-image) representing the 3D structure
of the contrasted blood vessel.

15   The surface rendering processing is processing of
rearranging volume data into a 2D pixel matrix so as to
render the data on the displaying unit 39 having a 2D
display screen. The image data is arranged as 2D
matrix data but expresses the 3D structure of the

20   object. In this case, therefore, this image will be
referred to as a 3D image in particular. In surface
rendering processing, first of all, the coordinate
position of the volume data is converted to a viewpoint
coordinate system. The viewpoint coordinate system for

25   the volume data (mask) coincides with that for the
volume data (DSA). In the surface rendering
processing, occlusion processing and shading processing

of shading an object surface are executed with respect
to the converted volume data. As a consequence, 3D
image data is generated. Surface rendering processing
for the volume data (mask) is performed for only voxels
5   having voxel values (CT values) within a range
corresponding to the bone. This generates a 3D bone
image. Surface rendering processing for the volume
data (DSA) is performed for only voxels having voxel
values (CT values) within a range corresponding to
10   the contrasted blood vessel. This generates a 3D
angio-image.

The image synthesizing unit 34 generates the 3D
image (mask) based on the volume data (mask) and
generates the 3D image (DSA) originated from the volume
15   data (DSA), by using the hidden plane removal
processing. The image synthesizing unit 34 synthesizs
the 3D image (mask) and the 3D image (DSA). As a
consequence, a synthetic image (3D angio/bone image) is
generated.

20   The 3D image processing of this embodiment is
characterized in that the 3D image (3D bone image)
representing the 3D structure of the bone and the 3D
image (3D angio-image) representing the 3D structure
of the contrasted blood vessel are independently
25   generated. Therefore, the 3D structure of the blood
vessel can be displayed by the color which is different
from the 3D structure of the bone. The 3D structure of

the blood vessel can be identified from the 3D structure of the bone. The observer can recognize the position of the blood vessel to the bone.

The 3D angio/bone image is displayed on the displaying unit 39 (see FIG. 10). In accordance with specifying operation by the operator, 3D angio display image or 3D bone display image is singly displayed on the displaying unit 39 in place of the 3D angio/bone image. The 3D displaying method is not limited to the surface rendering method. The volume rendering method, MIP(Maximum Intensity Projection), MinIP(Minimum Intensity Projection) or VED(Virtual Endoscopic Display) may be used.

As shown in FIG. 6, in the second 3D image process, 3D reconstruction processing is performed before subtraction processing. A plurality of mask images are subjected to 3D reconstruction processing by the 3D reconstruction processing unit 33. This generates volume data (mask). The volume data (mask) includes the 3D structure of the bone, the 3D structure of the soft tissue.

A plurality of contrast images are subjected to 3D reconstruction processing by the 3D reconstruction processing unit 33. This generates volume data (after injection of the contrast media) (see FIG. 9A). The volume data (after injection of the contrast media) includes the 3D structure of the bone, the 3D structure

of the soft tissue, and the 3D structure of the
contrasted blood vessel.

The volume data (mask) is subtracted from the
volume data (contrast) by the second subtraction
processing. As a consequence, volume data (DSA)
including only the 3D structure of the contrasted blood
vessel is generated.

The generated volume data (mask) and volume data
(DSA) are subjected to the same processing as that in
the first 3D image process.

As shown in FIG. 7, in the third 3D image process,
as in the first 3D image process, first of all, a
plurality of mask images are subtracted from a
plurality of contrast images to generate a plurality of
DSA images by the second subtraction processing.

The 3D reconstruction processing unit 33 then
generates volume data (after injection of the contrast
media) from a plurality of contrast images, and
generates volume data (DSA) from a plurality of DSA
images.

The volume data (DSA) is subtracted from the
volume data (after injection of the contrast media).
This generates volume data (mask) including the 3D
structure of the bone, the 3D structure of the soft
tissue.

The generated volume data (mask) and volume data
(DSA) are subjected to the same processing as that in

the first 3D image process.

In this embodiment, volume data including a bone structure and volume data including a contrasted blood vessel structure are separately generated from contrast images and mask images. Surface rendering is separately applied to the volume data including the bone structure and the volume data including the contrasted blood vessel structure. A 3D image representing the bone structure and a 3D image representing the blood vessel structure are generated. These two images are synthesized. The resultant image is then displayed. This makes it possible to display the precise blood vessel structure together with the bone structure.

In this case, the X-ray imaging apparatus incorporates the 3D reconstruction processing unit and 3D image processing unit. However, the present invention is not limited to this, and the X-ray imaging apparatus, 3D reconstruction processing unit, and 3D image processing unit may be independently arranged in an allowable combination. Soft tissues such as internal organs may be extracted in place of the bone from the volume data (mask).

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments

shown and described herein. Accordingly, various
modifications may be made without departing from the
spirit or scope of the general inventive concept as
defined by the appended claims and their equivalents.